Polarization Related Beam Experiments in the AGS

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AGS PP Related Beam Expts.

- Test horizontal tune jump quads at Ggamma=7.5.
- Polarization measurements on the up and down ramps.
- New CNI polarimeter detector test. -> Installation is not done yet, waiting for maintenance days after RHIC physics program starts.
- Rate dependence of polarimeter. ->Anatoli's presentation.
- BtA match studies. -> Leif's presentation.
- AGS model test with and without snakes. -> Nick's presentation.
- Manipulating β_x at snake entrances to reduce horizontal depolarizing resonance strength. Measure horizontal polarization profile with various settings. (Kevin/Keith) -> Nice results, but I don't have time to show it.
- Effect of different stripping foils on beam emittances. (Keith) Nice results, but I don't have time to show it.

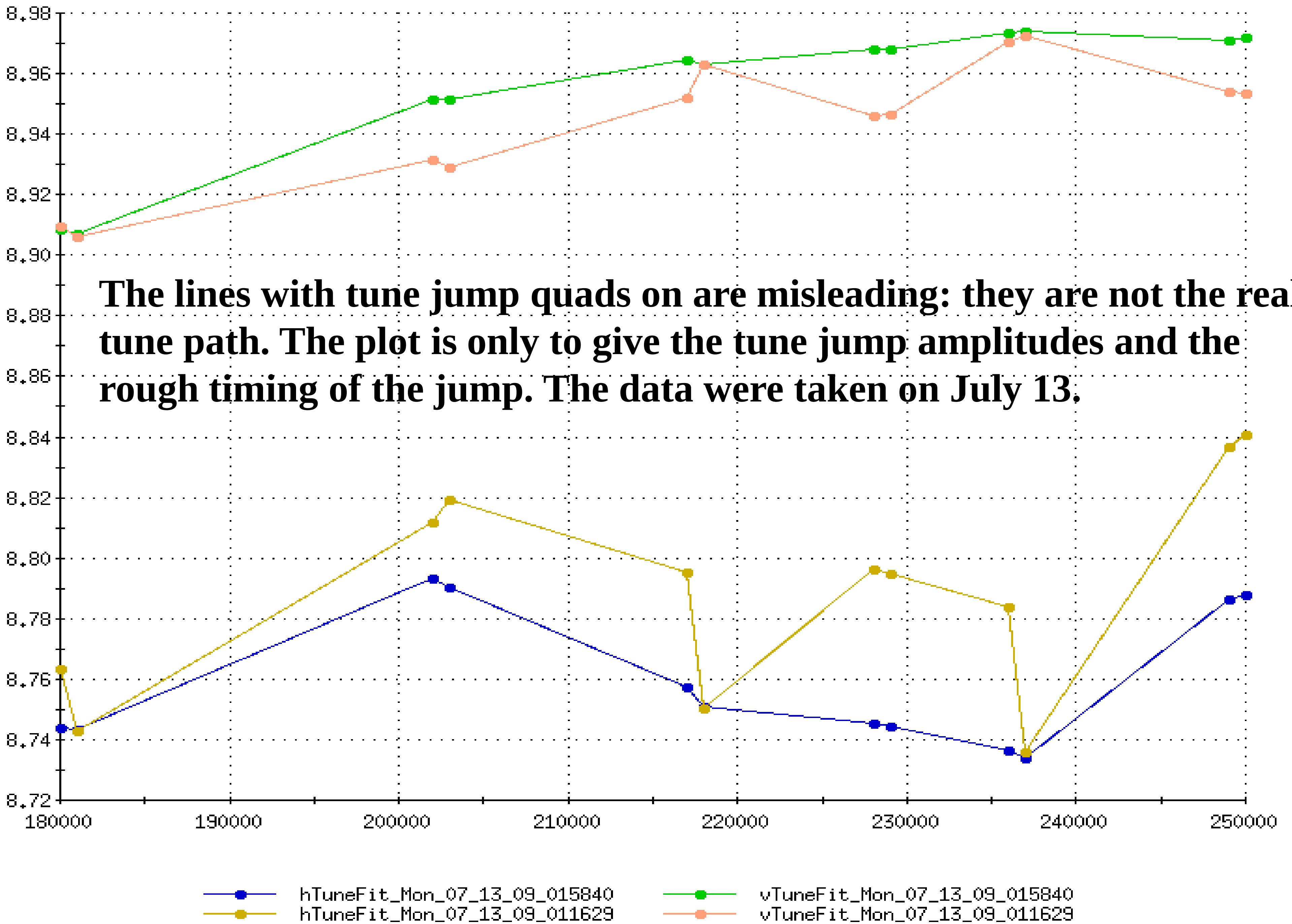
http://www.cadops.bnl.gov/AP/SpinMeeting/2009_0826_keith.ppt

Tune Jump for Horizontal Resonances

- Two fast quads have been installed at I5 and J5 sections.
- ν_x was changed by 0.04 in about 100 μs. This increases the crossing speed by about 4 times.
- Operation issue: has to be dead-reckoning of timing. For practical operation, we need to maintain the horizontal tune and radius constant throughout the ramp.
- Benefit on polarization transfer efficiency (for horizontal 15π beam):

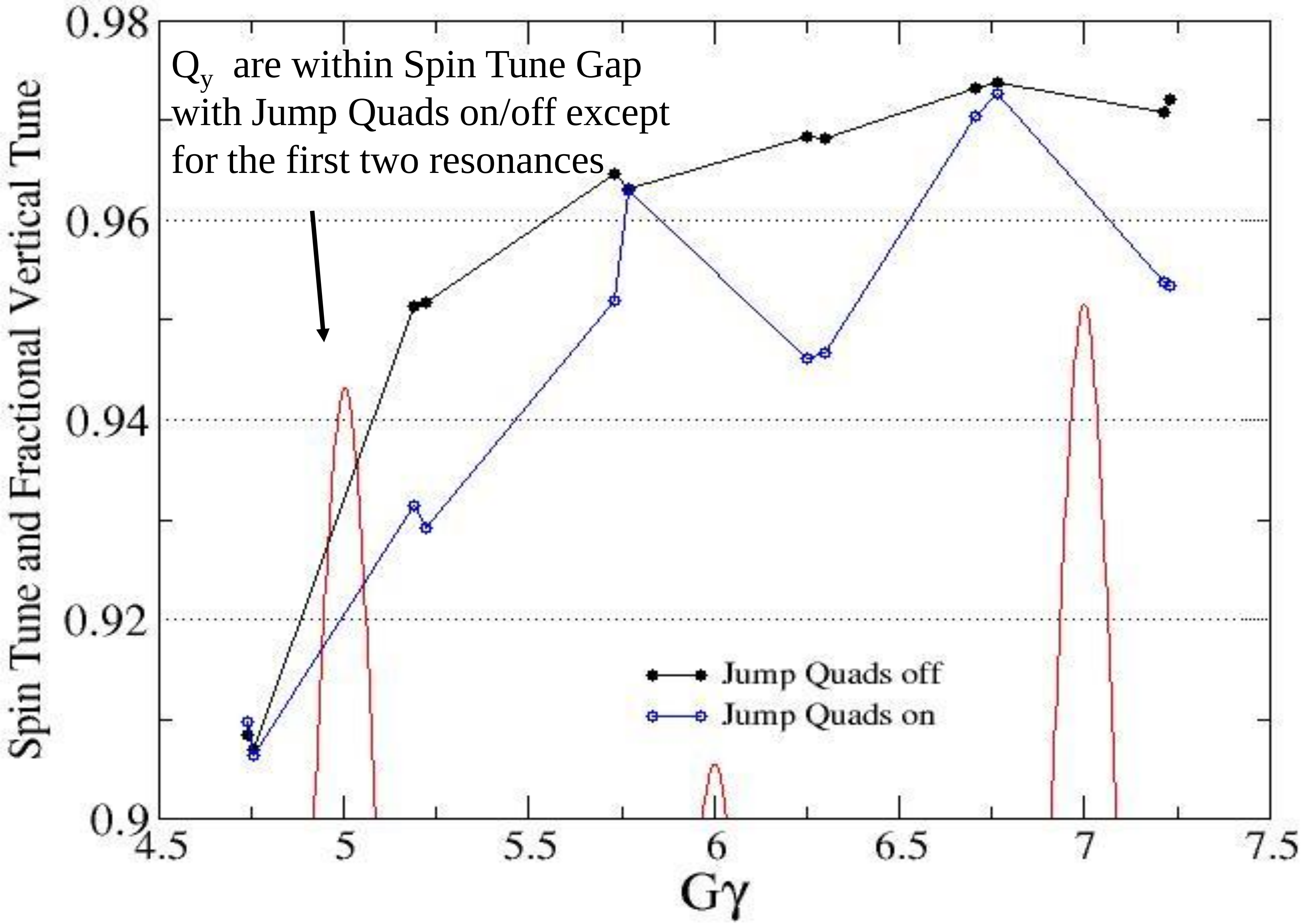
Crossing speed	P_f/P_i(peak)	P_f/P_i(whole)
regular speed	0.912	0.832
Double speed	0.955	0.912
4X speed	0.977	0.955

Betatron Tune Along Energy Ramp

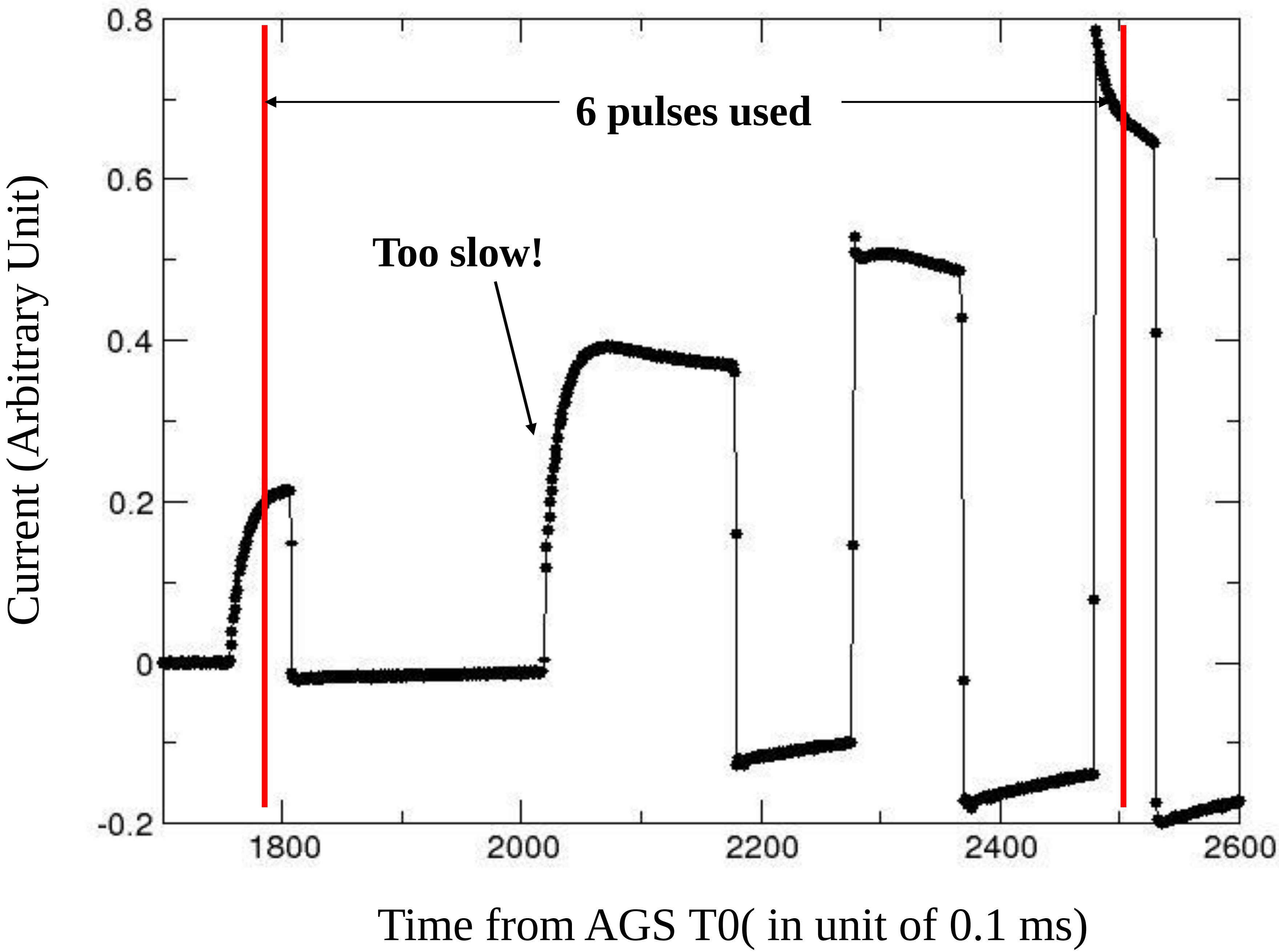


The lines with tune jump quads on are misleading: they are not the real tune path. The plot is only to give the tune jump amplitudes and the rough timing of the jump. The data were taken on July 13.

Q_y Path Relative to the Spin Tune Gap

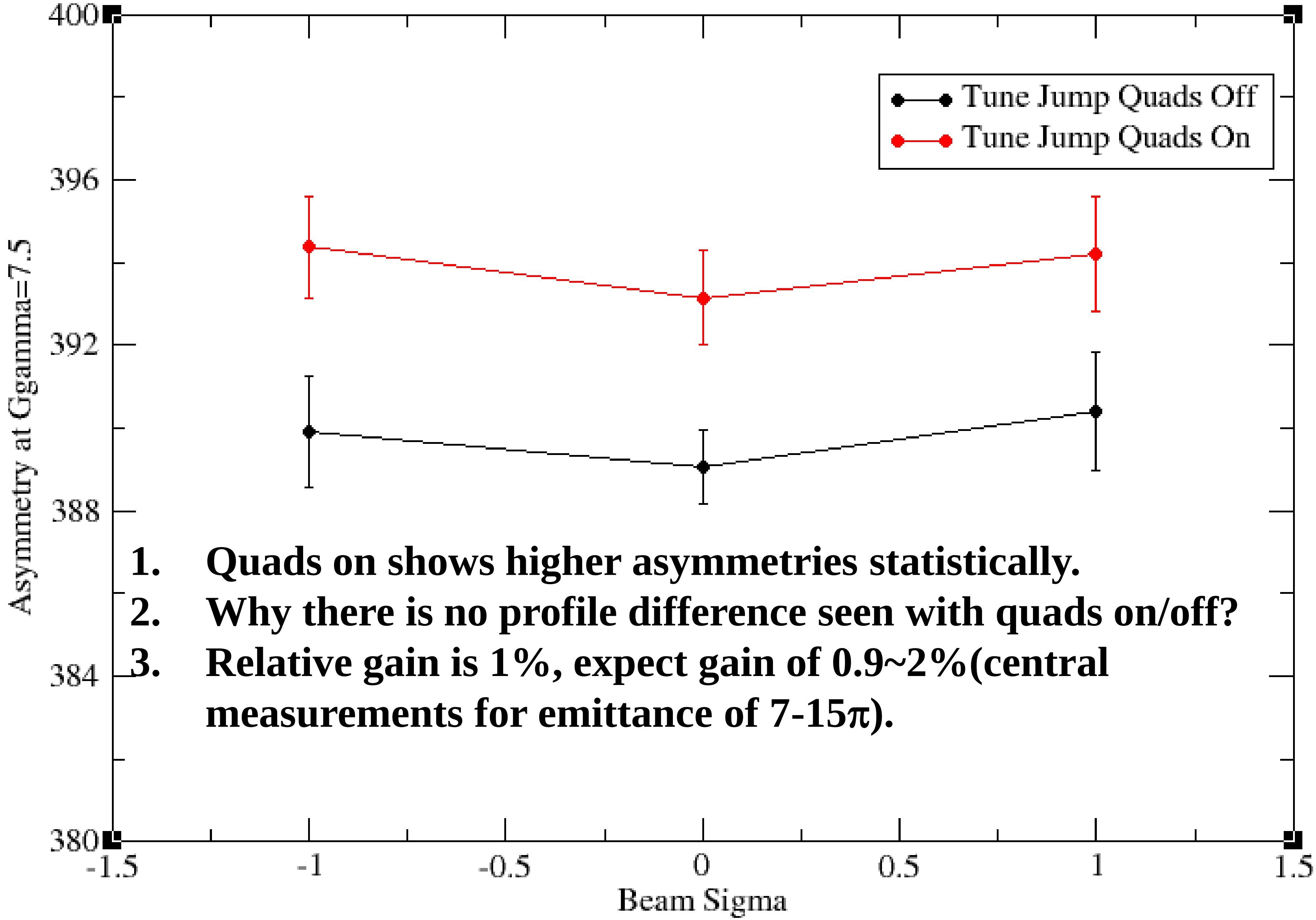


The HV Current of J5 Logged on July 13



Initial Results from Tune Jump Quads

Arbitrary unit



1. **Quads on shows higher asymmetries statistically.**
2. **Why there is no profile difference seen with quads on/off?**
3. **Relative gain is 1%, expect gain of 0.9~2%(central measurements for emittance of 7-15π).**

Model for the Data Analysis

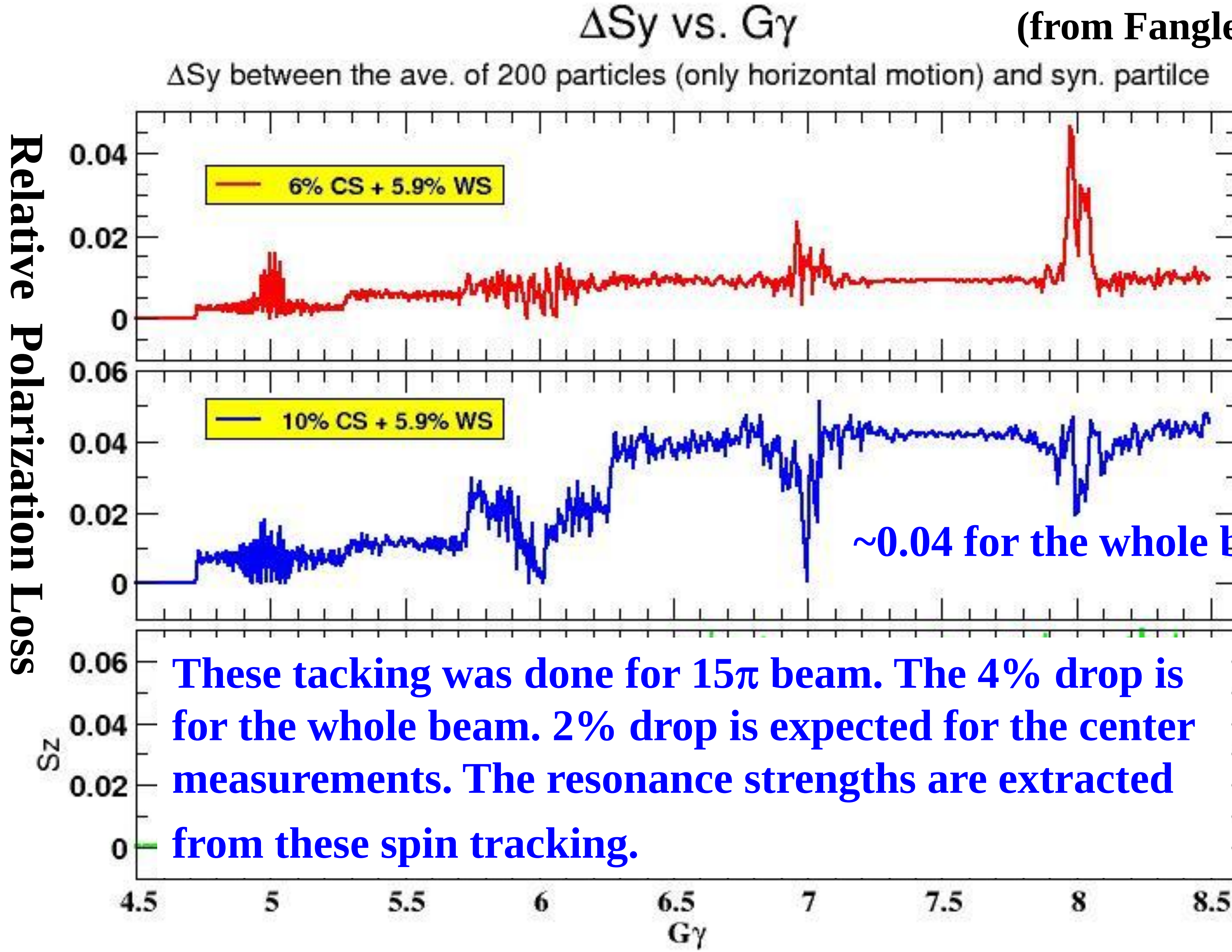
1 (at beam center)

$$\left\langle \frac{P_f}{P_i} \right\rangle = \prod_{n(\gamma)} \left[2e^{-\{[\pi K^2 \gamma (x - x_0)^2]/[\alpha(\gamma) 2\sigma^2]\}} \sqrt{\frac{1}{\frac{\pi K^2 \gamma}{\alpha(\gamma)} + 1}} - 1 \right], \tag{18}$$

- The resonance crossing speed α has two parts. The part from energy ramp can be derived from the Gγ GPM. The part from tune jump requires the information of tune jump amplitude (from tunemeter) and how fast the jumps are (from GPM of jump quads current).
- The Resonance strengths can be extracted from the spin tracking (Fanglei). It also requires horizontal emittance, which comes from IPM and CNI polarimeter target scan.
- The tune jump amplitudes can be derived from the actual tune measurements.
- Not all particles in the bunch benefit from the tune jump, especially for the N+ν_x resonances. The measured chromaticity and longitudinal beam size are used to determine the effectiveness of tune jumps.

Polarization Loss Near Injection for 15π Emittance

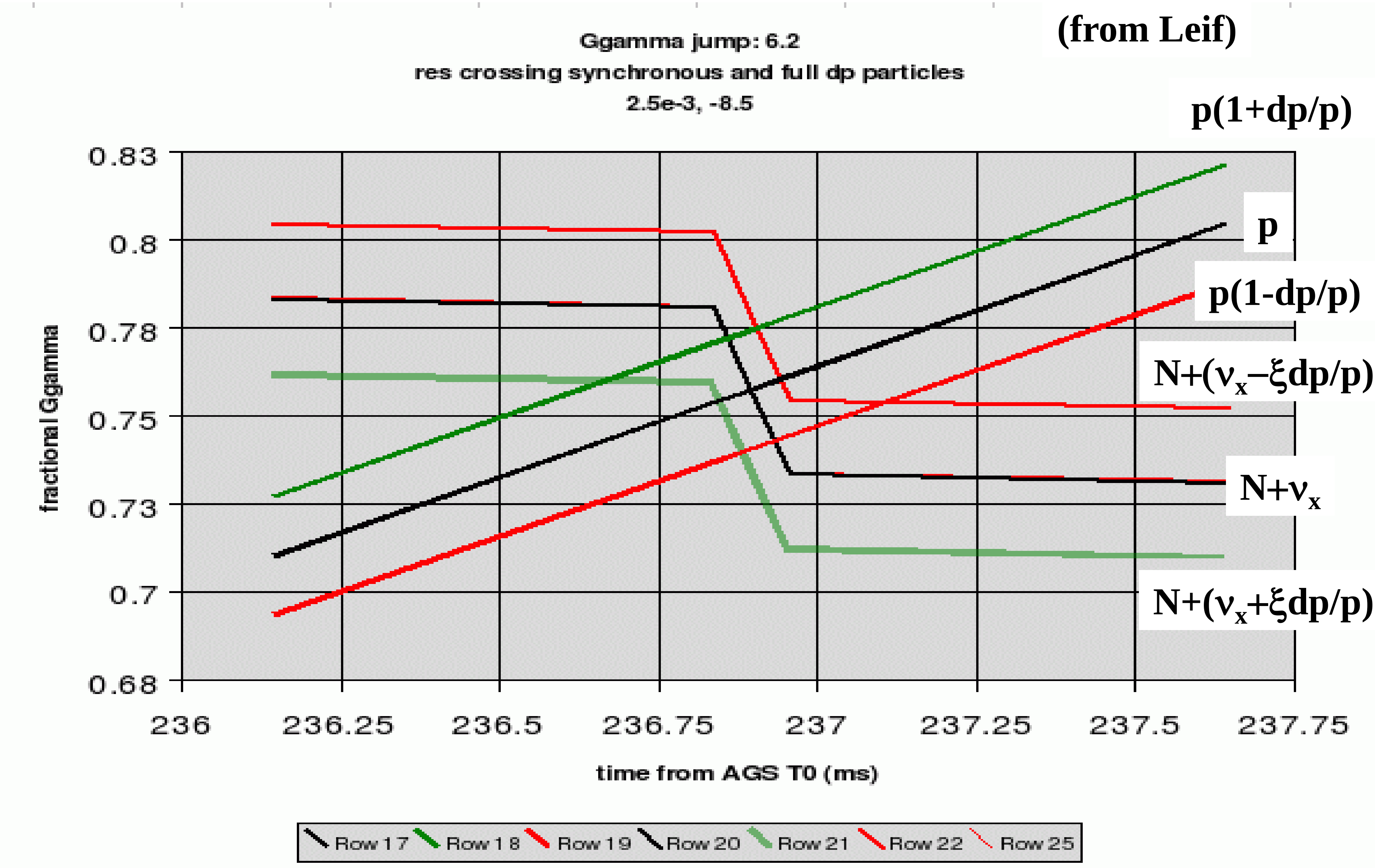
(from Fanglei)



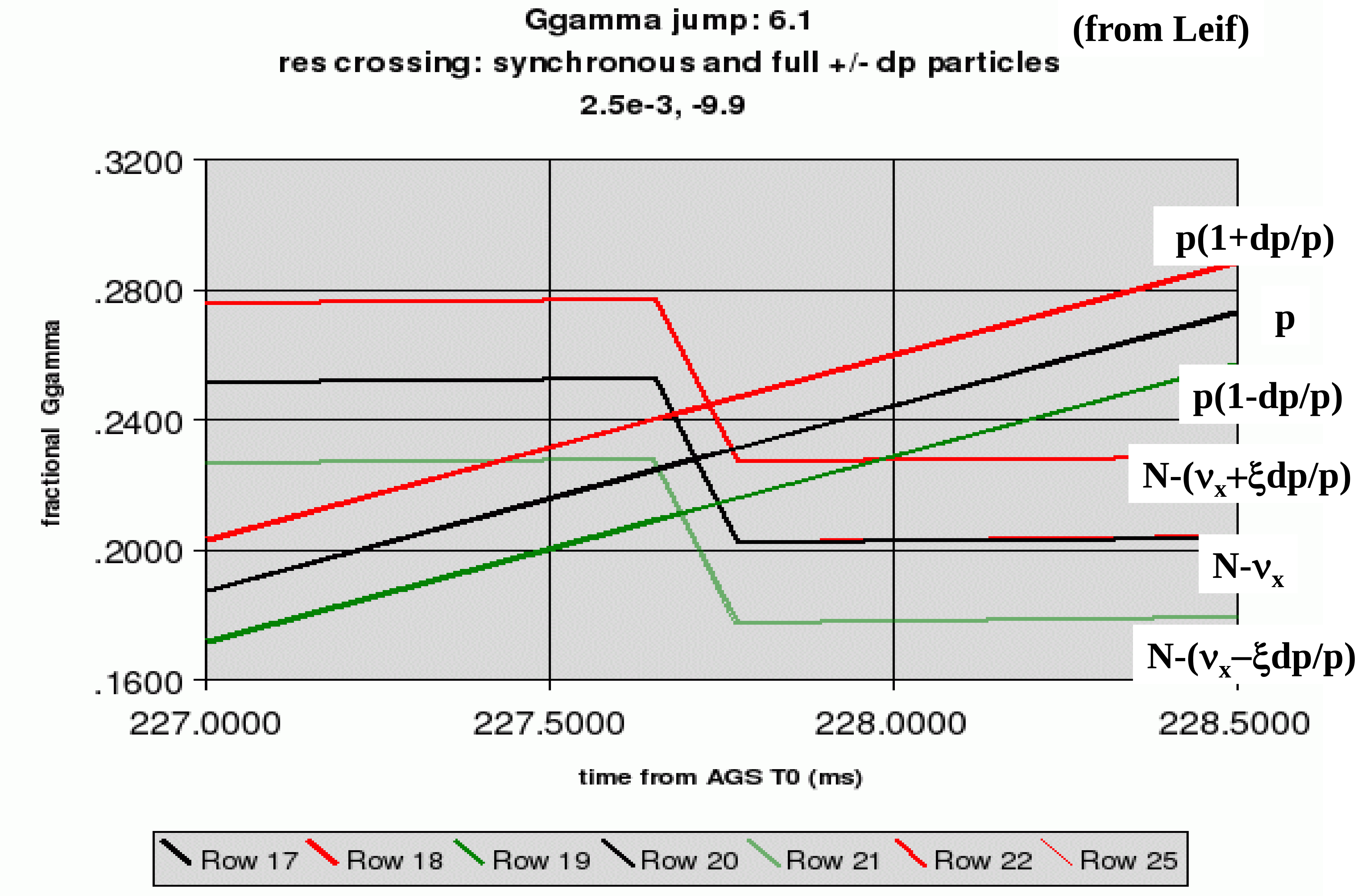
~0.04 for the whole beam

These tacking was done for 15π beam. The 4% drop is for the whole beam. 2% drop is expected for the center measurements. The resonance strengths are extracted from these spin tracking.

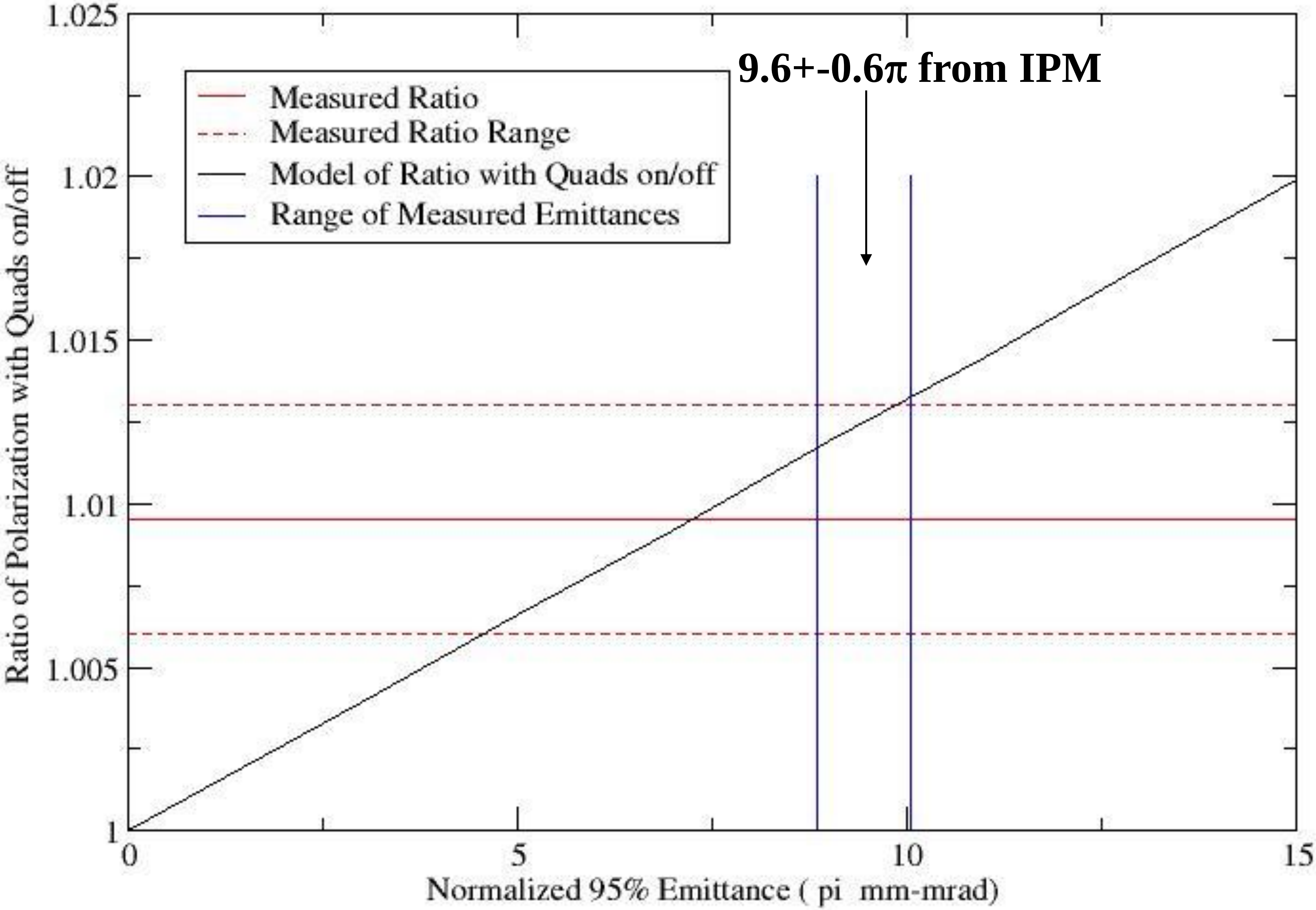
Tune Jump at $G\gamma = 6.73$ as an Example



Tune Jump at Gγ= 6.27 as an Example



Polarization Gain Ratio vs. Emittance



Summary of the Current Understanding

- The polarization gain factor can be explained by the model. But there are many parameters: the tune jump amplitudes and speeds; beam emittance; acceleration rate; resonance strengths.

- For the measured emittance (~9.6π) , the gain of polarization should be larger. However, the assumption here is that the timing of all jumps are perfect, which may not be the case.

- The flat profile is probably due to the weak horizontal depolarizing resonance strengths to start with. More data taking is needed to resolve the puzzle.

Thought on Commissioning in Run 10

- Due to the negative chromaticity, not all particles in the bunch benefit from the tune jump, especially for the $N+\nu_x$ resonances. Make the horizontal chromaticity close to zero helps. However, with vertical chromaticity close to zero, it is difficult to set horizontal chromaticity to zero, too. Another way to reduce the effect is to reduce the momentum spread, such as using h=6 instead of h=12.

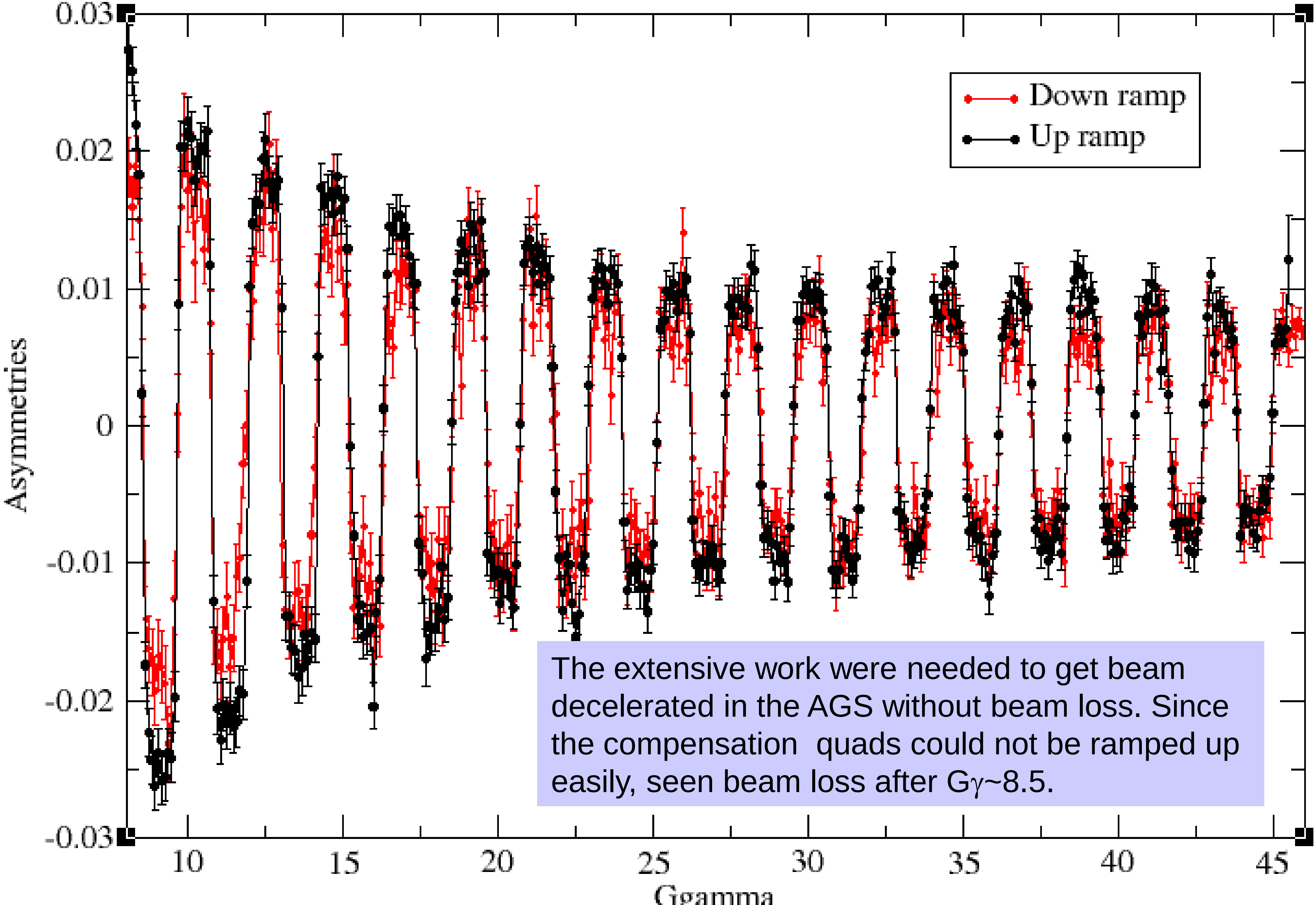
- To measure polarization profiles reliably, we need larger (wider) targets for the off-center target positions.

- At 1-sigma away position, the difference is too small to quantify the benefit of the tune jump method. The 2-sigma position will take too long. A position around 1.5-sigma may be better.

- The effect can also be enhanced if we can blow up only horizontal emittance. It has been demonstrated that this can be done with tune meter kicker on Mar.4, 2006. However, this probably can not be applied to early part of the ramp due to aperture limitation.

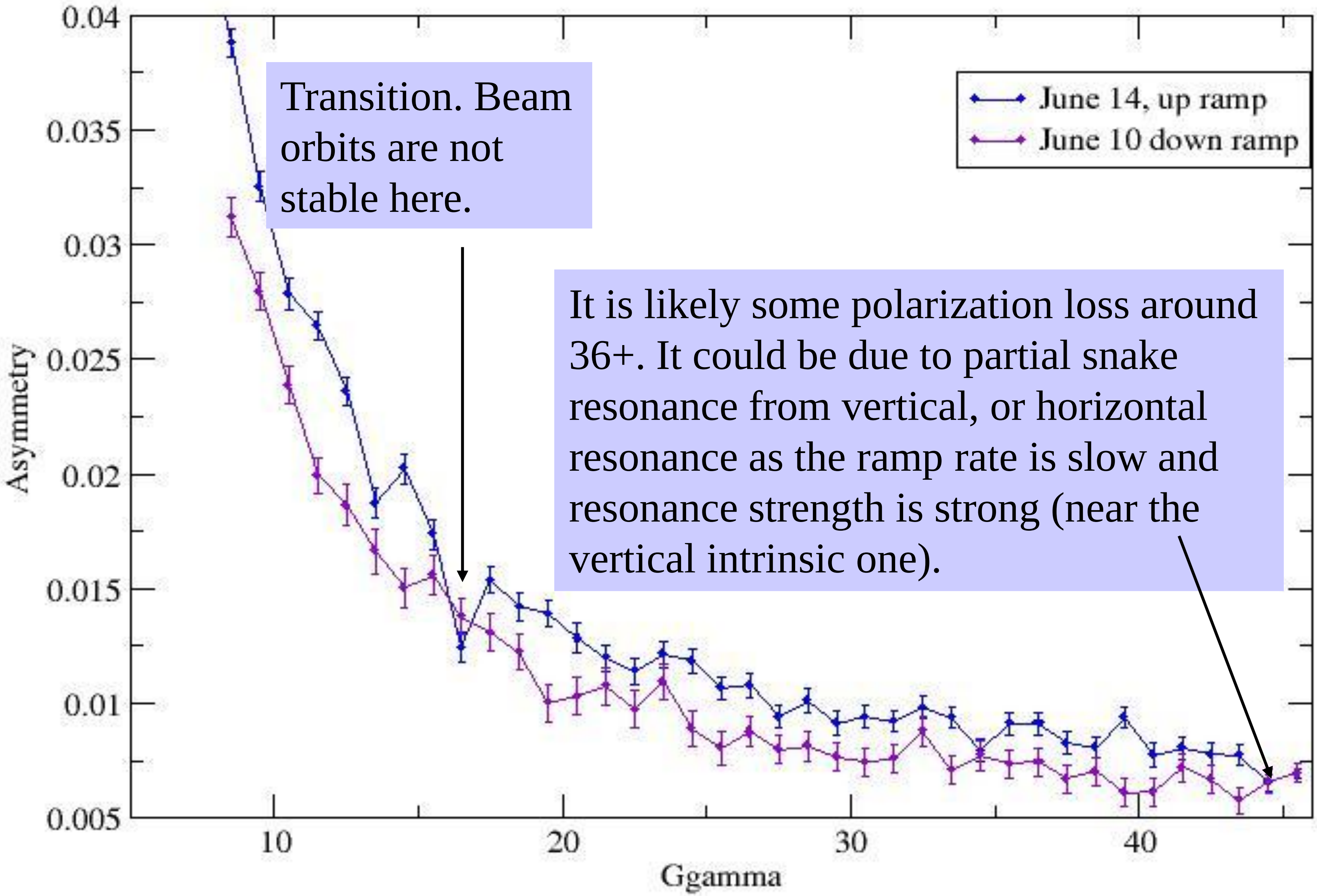
- We can scan some parameters:
  - Shift timing of the tune jump all together.
  - Scan tune jump amplitude (limited range: total of 0.04)

How Much Polarization Loss in the AGS?



The extensive work were needed to get beam decelerated in the AGS without beam loss. Since the compensation quads could not be ramped up easily, seen beam loss after Gγ~8.5.

Polarization Measurements on the Up and Down Ramps

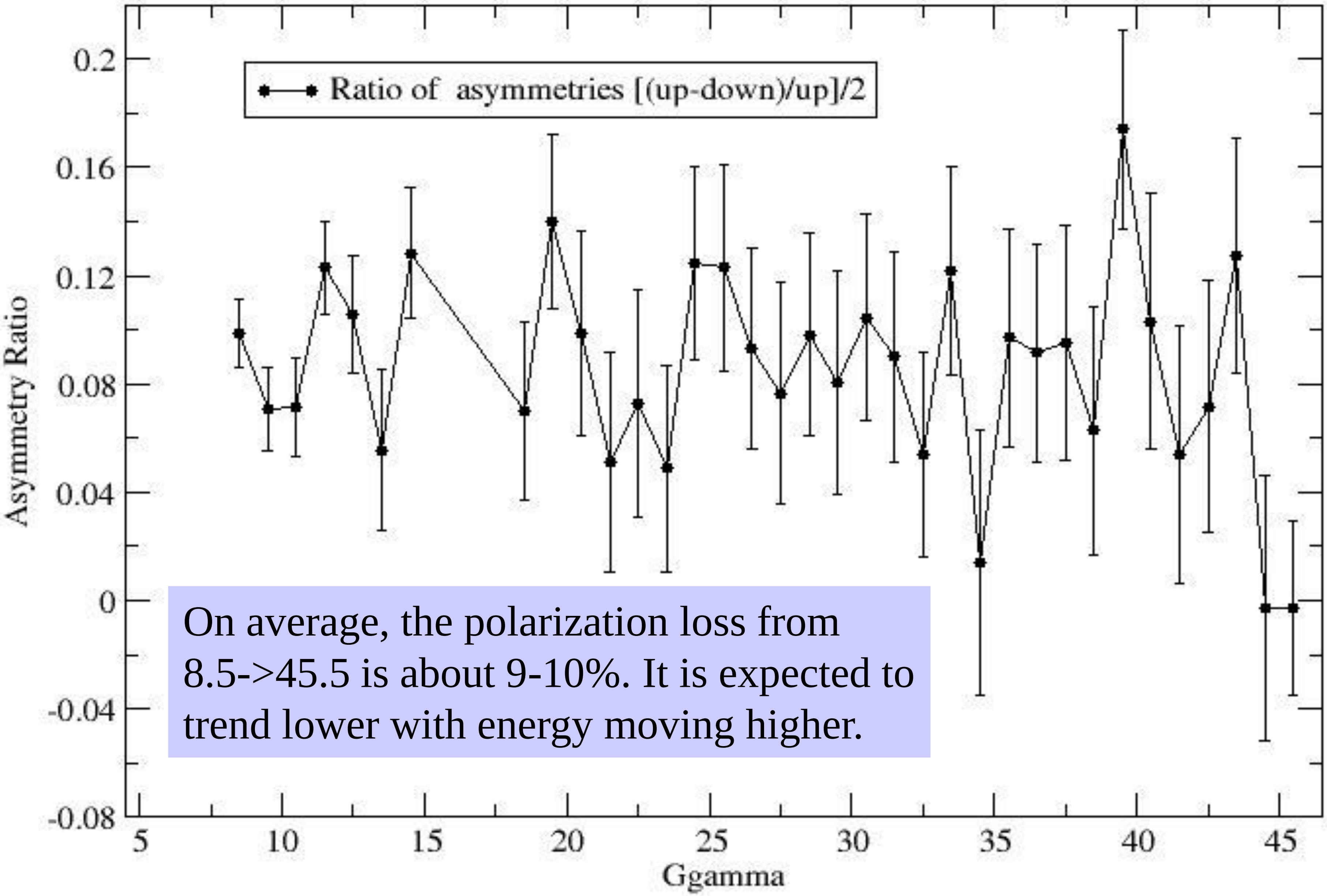


Transition. Beam orbits are not stable here.

It is likely some polarization loss around 36+. It could be due to partial snake resonance from vertical, or horizontal resonance as the ramp rate is slow and resonance strength is strong (near the vertical intrinsic one).

200 minutes data taking for each ramp. Need to take more to reduce error bars

Possible Polarization along the Energy Ramp



On average, the polarization loss from 8.5->45.5 is about 9-10%. It is expected to trend lower with energy moving higher.

New Si Detector and Electronics Test in the AGS

- Problems with the current system:
  - The rate problem experienced in both RHIC (250GeV) and AGS
  - The short life time of Si detectors (have to change them for each run, during run)
  - “high” polarization when using new detectors (with small leakage current)
- Different approaches are discussed in the polarimeter group. One will be tested in the AGS this coming run. The test is important to determine the direction of RHIC polarimeter upgrade.
- Proposed test will use Hamamatsu Si detectors (radiation hard) has been tested in RHIC in Run9. New electronics based on ADC and TDC will be tested. We are going to replace two 45 degree detectors with the new kind and they run with a new DAQ system.
- Si Detectors should arrive in coming days. The installation of new Si detectors and front end electronics will be done in a maintenance day.

Backup Slides

PP Related Beam Expts. For the Coming Run

- Rate dependence of polarimeter (using various targets).
- Ramp measurements for both up and down measurements, we need more statistics.
- New Si detector and electronics test.
- Overcome horizontal resonances with tune jumps.
  - Test the tune jump at $G\gamma=7.5$, with centered and 1.5 sigma target positions. Need a wider target to boost rate at off center positions.
  - Test tune jump with tunemeter kicker on at later half of the ramp. This requires that the tune jump timing be correct for more pulses.

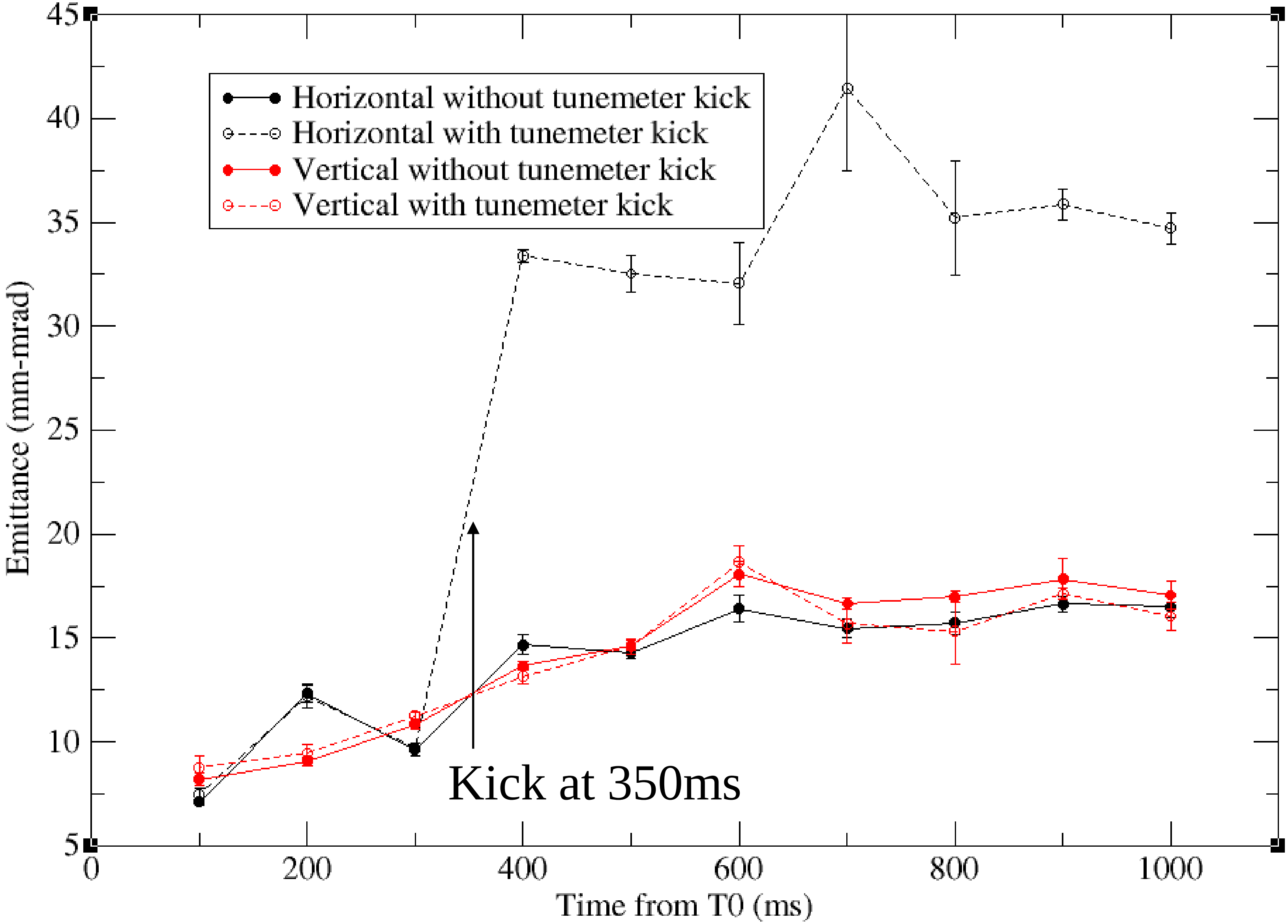
AGS CNI Polarimeter Rate Dependence

- The past data already shown that 600μm Carbon target can cause rate problem with intensity higher than $1.5*10^{11}$.
- This study is aimed to further quantify the effect.
- Measure polarization for the same beam using targets with different width.
- Measure polarization with two targets for various intensities (intensity scan).
- We have currently targets with three widths: 600μm, 250μm and 125μm.

Proof of Principle of Horizontal Tune Jump

- The overall effect is about 10+% for the whole ramp with nominal horizontal emittance. A direct way to measure the effect is to measure horizontal polarization profiles for the two cases (with and without jumps). But it is a lengthy measurement.
- Test the effect at a lower energy flattop such as $G\gamma=7.5$. The early part of polarization loss is quite large (~4% from modeling of early horizontal resonances) and the asymmetry is larger (~ five times) which makes a 4% difference measurable.
- The effect can also be enhanced if we can blow up only horizontal emittance. It has been demonstrated that this can be done with tune meter kicker on Mar.4, 2006. However, this probably can not be applied to early part of the ramp due to aperture limitation.
- We can scan some parameters:
  - Shift timing of the tune jump all together.
  - Scan tune jump amplitude (limited range: total of 0.04)

AGS Emittances along the Ramp

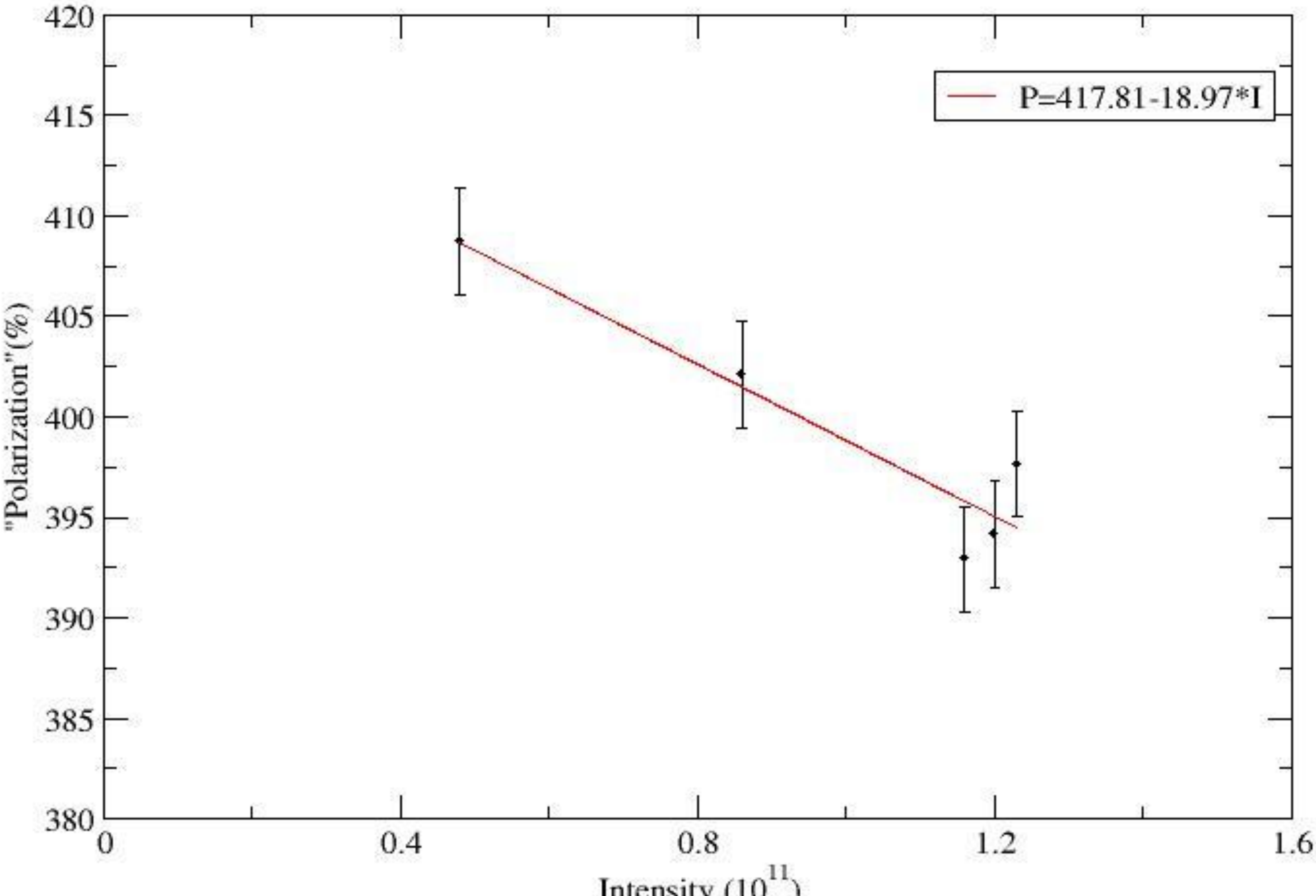


Data was taken on March 4, 2006 (Fanglei/Leif). The motion can be limited to horizontal plane only.

How Practical Is the Test?

- There was a series polarization measurements (four of each) with tune meter kick on/off in run6.
- There was a measurable effect: 54.7+-1.2% vs. 48.1+-1.4%. The polarization ratio (off vs. on): 1.14+-0.04
- A quick estimation from simple model with 31 π vs. 15π after 350ms (or $G\gamma$=26.5): 1.08. There could be additional polarization loss from coupling resonances which are not included in the simple model.
- A carefully planned study with enlarged horizontal emittances should be doable.

Intensity Scan at $G\gamma$=7.5



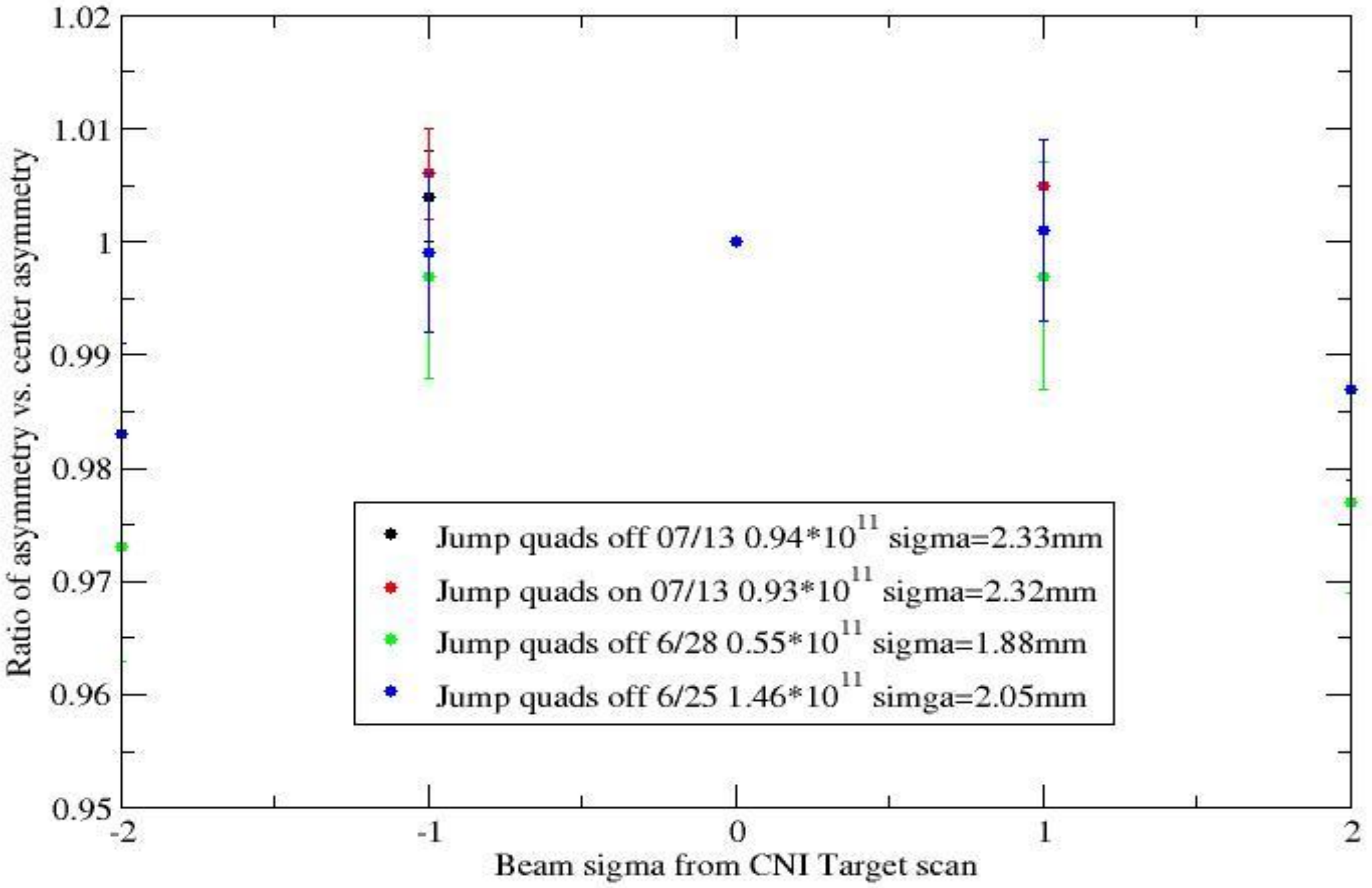
The correction on the asymmetry due to intensity difference between quads on and off is about 0.28 out of ~400.

Average Polarization and Other Measurements

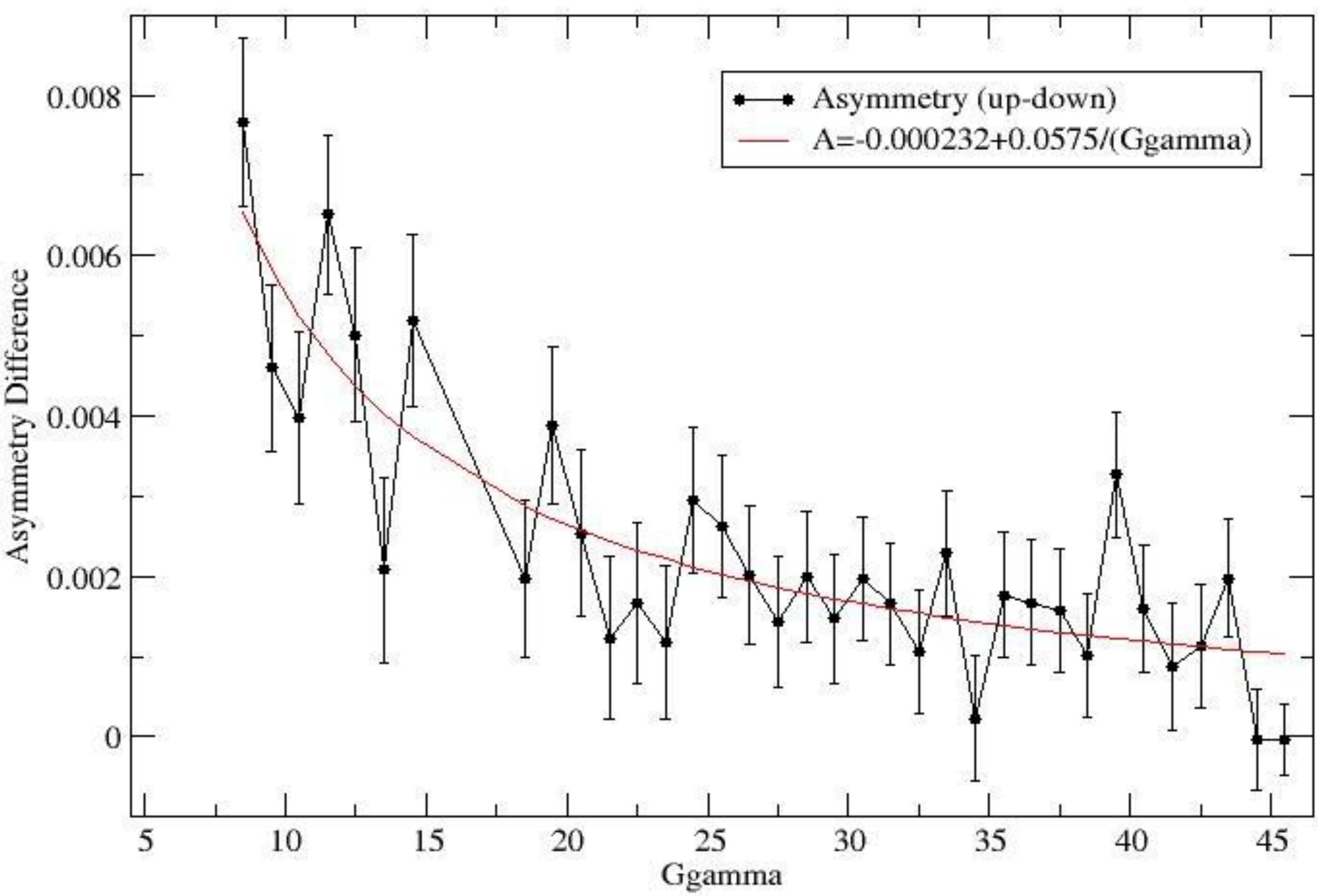
Quads	Target (σ)	Asymmetry ($X10^{-3}$)	Errors ($X10^{-3}$)	chi^2	Intensity ($X10^{11}$)	beam size (mm)
On	+1	394.386	1.416	0.345	0.925	2.31
On	0	392.553	1.019	1.370	0.931	2.33
On	-1	394.932	1.108	1.343	0.921	2.32
Off	+1	390.410	1.444	0.788	0.946	2.33
Off	0	388.296	0.903	1.464	0.945	2.35
Off	-1	389.950	1.376	0.867	0.929	2.32

- The intensities are about constant through the measurements. Beam sizes were also reasonably constant.
- For the central position, the ratio is about 3.1 σ:1.0095+–0.0035. The intensity effect has been compensated here.
- The average chi^2 are fine.
- The data quality is reasonably good.

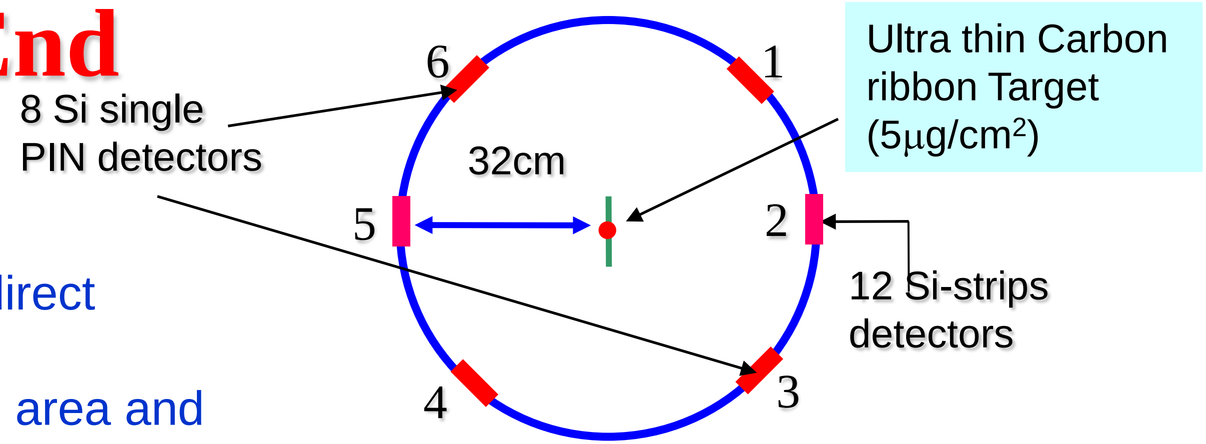
Normalized Polarization Profile Measurements



Polarization Measurements on the Up and Down Ramps



Detectors & Front End



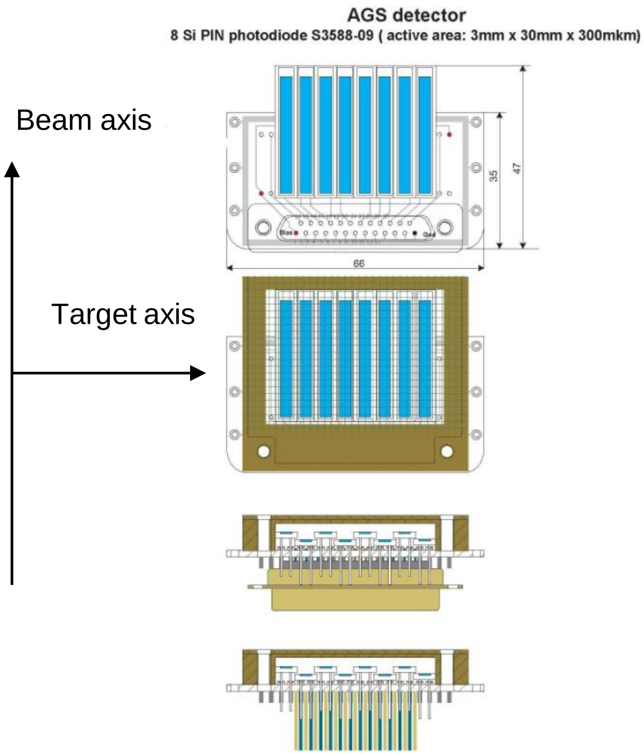
Detectors:

Hamamtsu Single PIN photodiode for direct detection (S3588-09)

Each detector has 30mm x 3mm active area and ~300 μm thickness and placed along the beam axis.

The typical dead layer is 60 μg/cm2

8 detectors/per port placed on the existing (+/- 45°) vacuum ports.



Front End:

Charge sensing Preamps/Shapers (MSI-8 & MSCF-16) connected to the detectors through the 0.5 m long low capacitance coax.

The Shaper has two outputs:

Digital (Time,CFD) – min delay 5ns with CFD –Walk: for 30ns input risetime, max 1ns (dynamic range 100:1)

Analog – σ = 100 - 400 ns.

PZ compensation: range 4 μs - ∞

Dynamic range: - 33 MeV

Shaper has remote control capability.